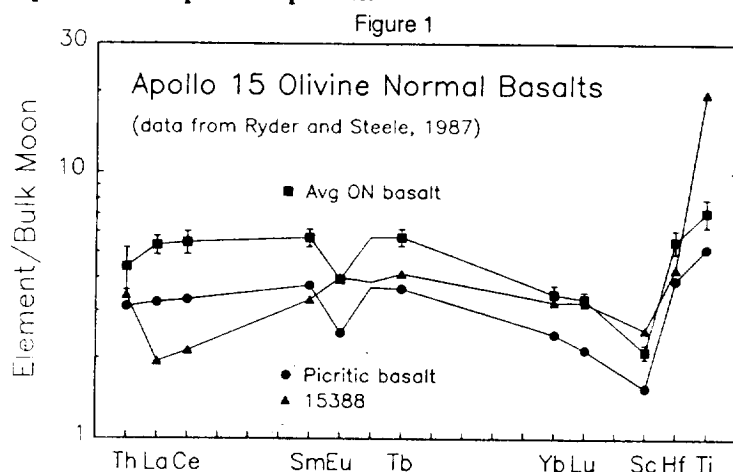


N 94-16258

PETROLOGIC MODELS OF 15388, A UNIQUE APOLLO 15 MARE BASALT; S.S. Hughes,

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Mare basalt 15388, a feldspathic microgabbro [1] from the Apennine Front, is chemically and petrographically distinct from Apollo 15 picritic, olivine-normative (ON) and quartz-normative basalts [2]. The evolved chemistry, coarse texture, lack of olivine, and occurrence of cristobalite in 15388 argue for derivation by a late-stage magmatic process that is significantly removed from parental magma. It either crystallized from a magma evolved from the more mafic Apollo 15 basalts, or it crystallized from a currently unrepresented magma. Rb-Sr and Sm-Nd isotopic systematics [3] yield isochron ages of 3.391 ± 0.036 and 3.42 ± 0.07 Ga, respectively, and $\epsilon_{Nd} = 8.6 \pm 2.4$, which is relatively high for Apollo 15 mare basalts. In contrast to chemical patterns of average Apollo 15 ON basalts and Apollo 15 picritic basalt (Figure 1), 15388 has a strongly positive LREE slope, high Ti, shallower HREE slope and a slightly positive Eu anomaly. These features argue against 15388 evolution by simple olivine fractionation of a parental ON or picritic basalt magma although olivine is a dominant liquidus phase in both potential parents.



Modal mineralogy suggests that the chemistry may be explained by accumulation of observed minerals pyroxene ("bow" shaped REE), ilmenite (high Fe, Ti), and plagioclase (Eu anomaly) from an evolved ON magma [4]. In this scenario, elevated trace element abundances would require at least 88% crystallization prior to 15388 accumulation, but 15388 is not significantly depleted in Mg, Cr, Co, etc., as would be expected after much evolution by mafic mineral (and plag) fractionation. This discrepancy could be related to successive batches of ON magma reintroduced into, and mixing with, the evolving 15388 parental magma; however, enrichments of LILE would

become diluted by low-LILE magma. One possibility is to assume that crystallization prior to 15388 cumulate deposition was essentially an equilibrium process throughout the crystallization history. Extensive fractionation of LILE in the original magma would be allowed, yet compatible elements would not be severely depleted. Alternatively, extensive fractionation of the primary magma may not be required such that elevated LILE in the 15388 cumulate can be related to entrapment of small amounts of the evolving liquid into the crystalline mush.

In order to demonstrate the possibility of 15388 being non-exotic relative to other Apollo 15 basalts, petrologic models assume that later stage cumulate phases contributed to the bulk chemical signature and the most likely parental magma was equivalent to an Apollo 15 ONB, the compositions of which span a fairly restricted range controlled by ~10 percent olivine fractionation [2]. The actual precursor magma composition could be any of the ON basalts, the only difference being amount of olivine crystallization. Other potential models, including any that depict 15388 as a primary magma or a cumulate from some unknown Apollo 15 magmatic composition, introduce complexities that are possibly nonessential to 15388 petrogenesis. Source hybridization models, using technique of [5], yielded no viable mechanisms by which the trace element pattern of 15388 could be derived as a primary mafic magma, albeit a normative olivine-free one. Models (Table 1) predict the major element composition by accumulation of 15388 mineralogy from an evolved ON composition using crystal/liquid molar partition coefficients appropriate to low alkali systems [6]. Trace element partition coefficients are those used by [5], except for pyroxene [7].

In model #1 (Figure 2), an ON magma first evolves by 75% equilibrium crystallization of 12% ol + 62% px + 26% pl, the normative mineralogy of an average ON basalt. From this liquid, accumulation of 59% px + 31% pl + 10% ilm closely reproduces the observed 15388 major element composition in Table 1. Within errors associated with the average ON composition used as a primary magma, trace element abundances are not predicted by this scenario. Also, precursor crystallization using an equilibrium process involving normative mineralogy is excessive and presents an unlikely petrologic scenario.

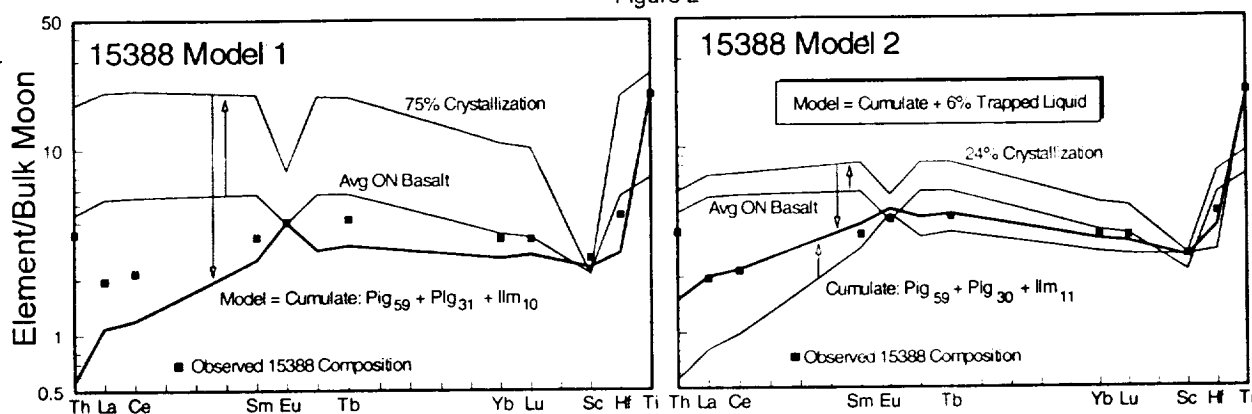
Model #2 yields a better prediction of 15388 chemistry and a more reasonable amount of precursor crystallization of the primary magma. Because the 15388 composition lies very close to the olivine control line [2] for the ON series, evolution of the primary magma was probably related to olivine-only crystallization. After 24% olivine (step-wise equilibrium) crystallization of the ON basalt magma, a modeled accumulation of 59% px + 30% pl + 11% ilm closely predicts the major element composition of 15388 but fails to yield an appropriate trace element signature. Addition of 6% trapped liquid to this cumulate does not appreciably change major element abundances, yet provides a reasonable approximation, within observed uncertainties, of the trace element signature.

Drawbacks to model #2 are unpredicted Th and Cr abundances. Trace element signatures (Figure 1) suggest that Th in 15388 cannot be related to any process of closed system evolution of ON magma unless a phase compatible to Th and incompatible to LREE is present. Assuming the reported

value of Th is correct, the only possible alternatives would have to include contamination by an unrepresented composition. Cr values may be less difficult to predict by assuming either a small amount of chromite was included in the initial ol crystallization or that Cr partitioning in ol was higher. Modeling supports a cumulate scenario; however, the depleted nature of the LREE is consistent with direction but not the degree of ϵ_{Nd} . The chemical model suggests that an open system is not a significant requirement for 15388 evolution, but the discrepancy in Th prediction, high ϵ_{Nd} , and the trapped liquid requirement argue for a possible exotic component.

Table 1.			Model #1		Model #2		
	15388	Average ONB	75% Crystall.	Px-Pl-Ilm Cumulate	24% Ol Crystall.	Px-Pl-Ilm Cumulate	Cumulate + TL
SiO ₂ (%)	44.2	45.9	42.4	43.4	48.6	42.8	43.3
TiO ₂	5.9	2.1	7.7	5.9	2.8	5.8	5.5
Al ₂ O ₃	11.1	8.9	4.3	11.8	11.7	11.4	11.5
FeO	19.8	21.8	27.5	20.4	19.3	20.9	20.7
MnO	0.35	0.35	0.44	0.33	0.31	0.34	0.34
MgO	8.0	10.9	4.1	7.8	4.0	7.9	7.6
CaO	10.2	9.5	12.3	10.0	12.3	9.8	10.1
Na ₂ O	0.32	0.26	1.01	0.20	0.34	0.07	0.20
K ₂ O	— (est.)	0.04	0.16	0.06	0.05	0.01	0.07
Cr ₂ O ₃	0.34	0.59	0.09	0.11	0.62	0.78	0.77
Sc (ppm)	48.6	40.4	40.0	43.8	49.3	48.4	47.8
Co	41.9	52.5	45.6	55.9	35.5	35.3	35.1
Hf	1.82	2.32	8.11	1.15	3.04	1.14	1.54
Th	0.43	0.55	2.18	0.07	0.72	0.07	0.19
La	1.75	4.8	18.3	0.98	6.32	0.73	1.8
Ce	5.0	12.8	48.6	2.8	16.9	2.3	5.1
Sm	1.89	3.25	11.30	1.44	4.68	1.60	2.16
Eu	0.84	0.83	1.61	0.84	1.15	0.90	0.96
Tb	0.58	0.80	2.68	0.42	1.15	0.48	0.60
Yb	1.98	2.12	6.58	1.57	3.01	1.62	1.90
Lu	0.30	0.31	0.95	0.25	0.44	0.24	0.28

Figure 2



REFERENCES: [1] Dowty E. et al. (1973) PLPSC-4, 423-444. [2] Ryder G. and Steele A. (1987) LPSC-18, 862-863. [3] Dasch E.J. et al. (1989) LPSC-20, 218-219. [4] Ryder G. (1989) PLPSC-19, 43-50. [5] Hughes S.S. et al. (1988) GCA 52, 2379-2391. [6] Longhi J. and Pan V. (1988) J. Petrol. 29, 115-147. [7] McKay G. et al. (1986) GCA 50, 927-937.